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THERMAL PERFORMANCE AND DELIVERY CAPABILITY OF A 350-LITRE ELECTRIC STORAGE WATER HEATER

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ABSTRACT

A prototype 350-litre (nominal) electric storage water heater was tested in accordance with selected clauses of CSA Standard C191. Except for the standby energy loss, for which there is no specified maximum for this size of tank, the performance of the water heater was consistent with the CSA Standard. The standby loss was 161 W. This can be reduced in production models, by using high density fibreglass insulation and good assembly practice. This larger tank is capable of supplying hot water in residential applications requiring more than 800 litres per day. In load management applications the tank can supply 285 litres during the 16 hour on-peak period. This volume of hot water is marginal for residential applications. However, it may be useful for load management, where daily hot water consumption is less than 285 litres/day. Possible applications are senior citizens homes, small condominiums and some types of apartments.

Introduction

The majority of residential storage water heaters have a capacity of 175 or 270 litres. These water heaters are economical and meet most residential requirements. However, there is a need for a larger tank which can store and deliver more hot water. Consequently, a 350-litre electric storage water heater was developed, by a Canadian manufacturer, to meet this need.

The prototype 350-litre (nominal) electric storage water heater was tested in accordance with selected clauses of CSA Standard C191/1/. In addition, a load management test was performed to determine whether the tank is suitable for load management in single and multi-residential buildings. This report presents the results of this test program.

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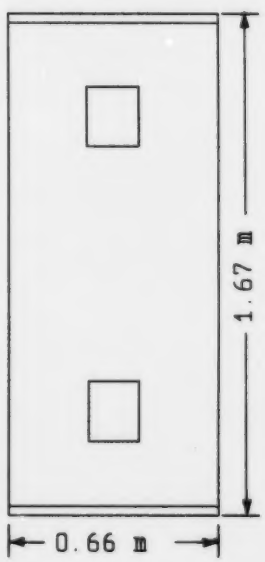
Tank Description

Figure 1 is a schematic of the 350-litre tank. The diameter is the same as a standard 270-litre water heater; however, the height is increased. Tank construction is consistent with standard electric water heaters. The storage tank is made of steel with the inner surface coated with glass. The water heater is designed to be insulated with high density fibreglass (32.04 kg/m^3). However, for these tests low density fibreglass was used. The tank and insulation are covered by a sheet metal shroud. Thermostats are surface mounted, and wired for flip/flop operation. The elements are standard flanged immersion elements, rated at 4500 W (nominal). Table 1 lists the tank dimensions and other characteristics.

Table 1
Tank Characteristics

height	1.67 m (65.5 inches)
diameter	0.66 m (26 inches)
volume	350 L (80 gal)
material	steel/glass
elements	4500 W/4500 W

Figure 1
350 L Electric Storage Tank
Dimensions



Test Methods and Instrumentation

The following tests, described in CSA Standard C191 series M1983, were performed to establish the thermal performance and delivery capability of the 350-litre water heater.

Energy Efficiency	clause	5.6
Delivery		5.11
Tank Capacity		5.4
Diffusion		5.7
Upper zone		5.10
Heater Element Input		5.5

The delivery test was conducted using the newly proposed CSA draw schedule for 270 L tanks (Appendix A). Daily water draw volume was 630 litres.

An off-peak delivery test was performed to determine the maximum amount of water which can be drawn before the temperature difference between the outlet and inlet water temperature, (T_{out}-T_{in}), drops below 44°C.

All tests were performed at Ontario Hydro's water heater test facility. Tank temperatures, water flow rates, and electrical energy consumption were recorded using a HP3497 data acquisition system controlled by a microcomputer. All data were recorded, verified and stored in machine readable form for analysis.

Test Results and Discussion

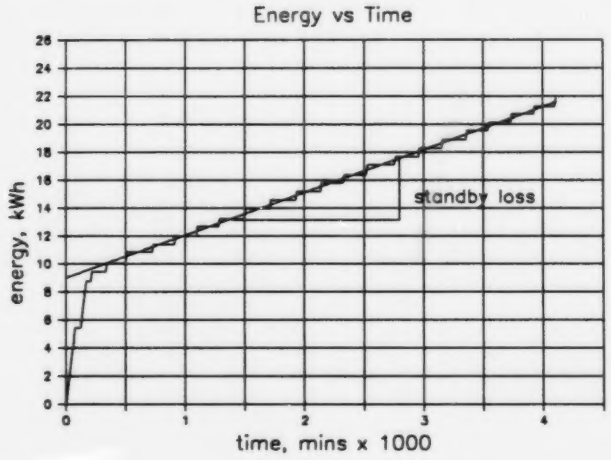
Table 2 summarizes the energy efficiency (standby loss) test results. Tank capacity was measured using a turbine flowmeter. Total volume, at line pressure, is 362 litres. Figure 2 shows the energy efficiency test graphically. The uniform step increase in energy consumption, as a function of time, indicates a well-controlled test.

The standby loss was 161 W. This is relatively high for a tank this size. The use of high density fibreglass insulation and proper installation should be sufficient to obtain a lower standby loss.

Table 2
Standby Test Results

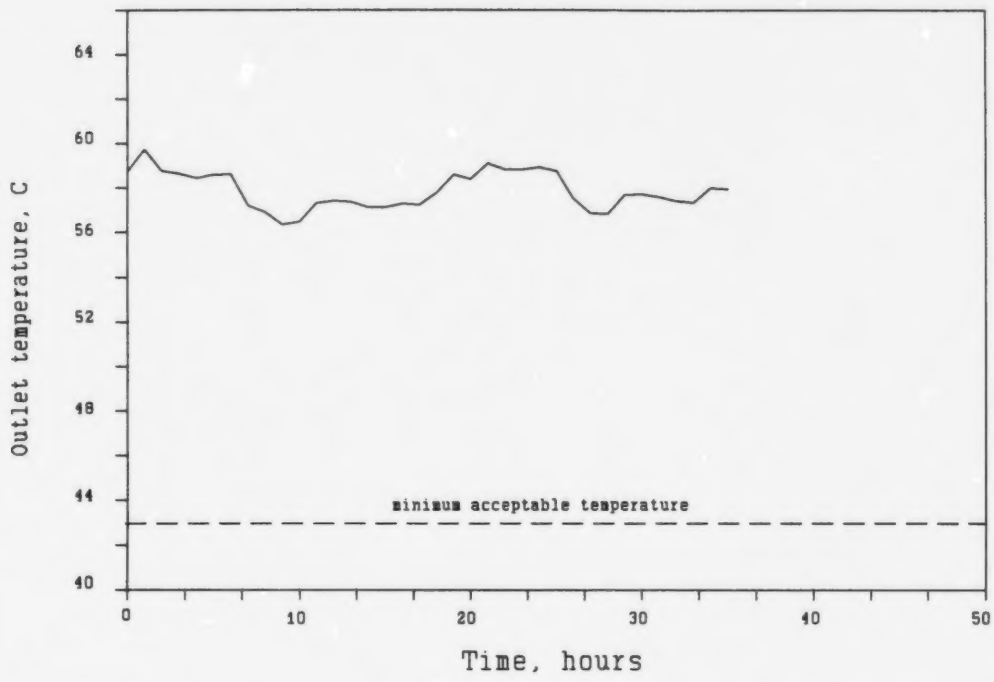
Tank Capacity (litres)	Standby Loss (watts)
362	161

Figure 2
Standby Test



The delivery requirement was met by this tank. The tank has sufficient storage and installed power to meet a daily withdrawal of 630 litres. A water heater is deemed to have failed a delivery schedule if the temperature difference (T_{out} - T_{in}) drops below 44°C, except that one draw may drop to 39°C above the inlet temperature. Figure 3 clearly shows the outlet water temperature was always above the 44°C limit. The average inlet water temperature, for all the tests was 4.5 $\pm$ 1.0°C.

Figure 3
Delivery Test - 630 L
Outlet Temperature



During the delivery test, both energy supplied as hot water and electricity were recorded. The energy output as hot water divided by the energy in as electricity is the operating efficiency of the tank. Over a two day test period, 75.3 kWh of energy were delivered as hot water and 83.6 kWh of electricity were used. This gives an efficiency of 90.4%. Figures 4A and 4B show the total amount of energy as hot water and electricity used during the test.

Figure 4A
Electrical Energy

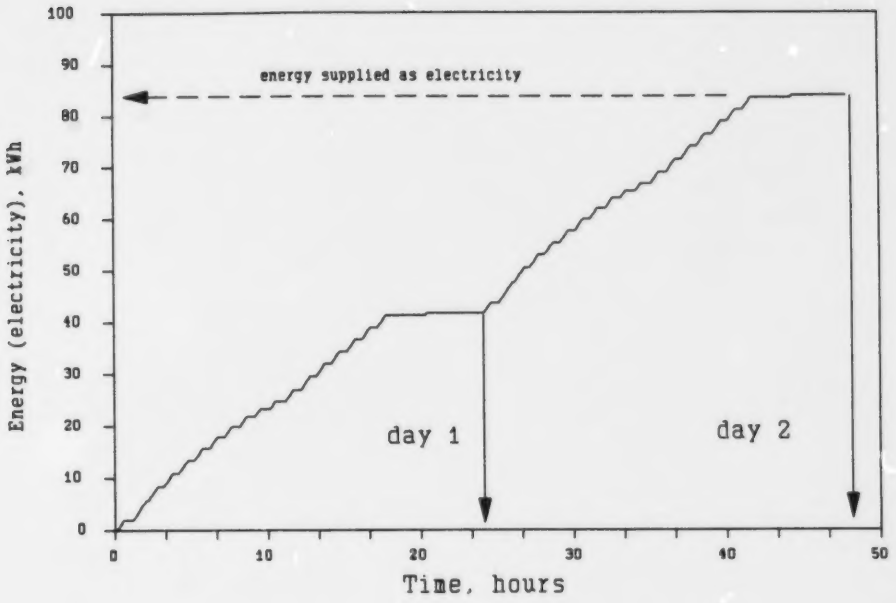
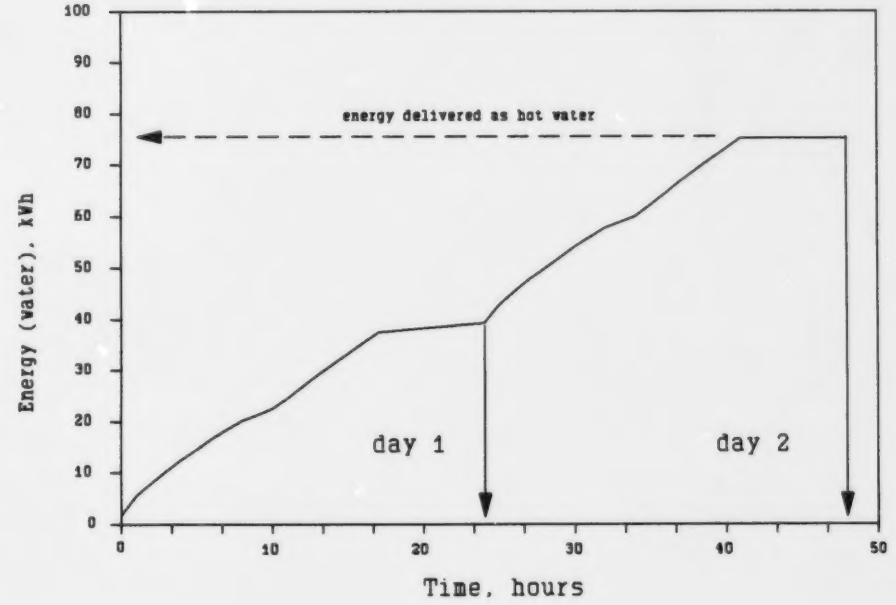
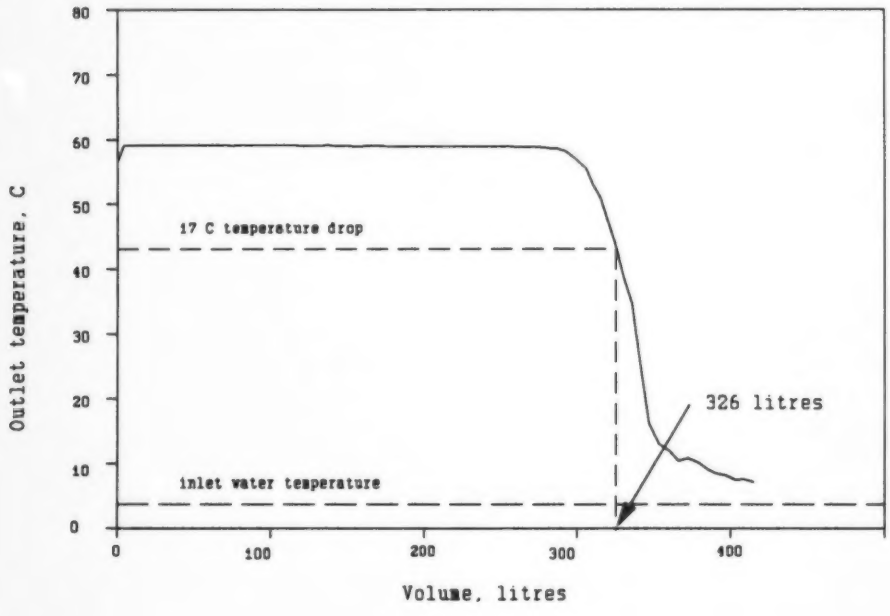


Figure 4B
Energy as Hot Water



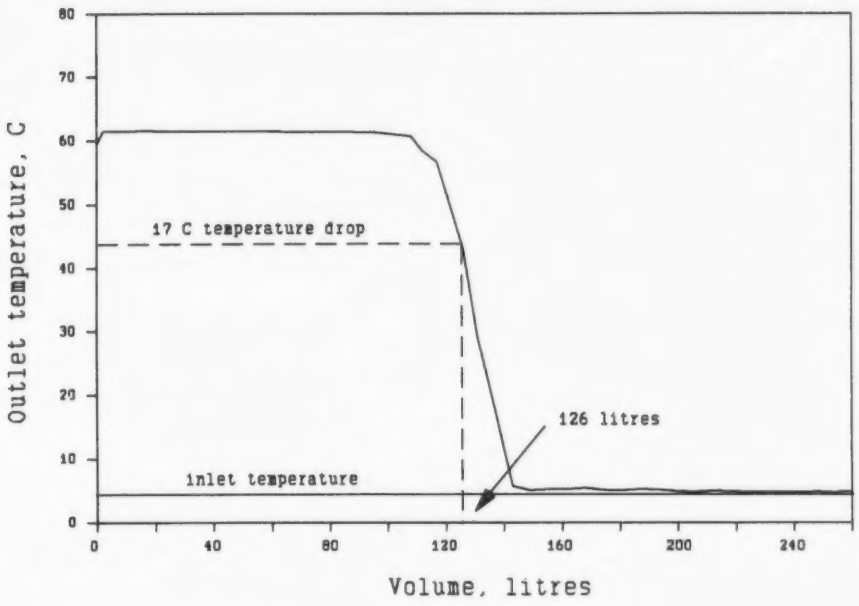
The diffusion test indicated that the percentage total tank volume of delivered hot water before the outlet temperature dropped 17°C, was 326 litres or 90%. This is the minimum requirement for this test. Figure 5 shows the outlet temperature versus volume of water flowed, during the diffusion test.

Figure 5
Diffusion Test



The upper zone test measures the amount of water heated by the upper element. The test consists of heating a cold tank with only the upper element, until the upper thermostat shuts off. The thermostat is set for a 56°C temperature rise above the inlet water temperature. Water is drawn off at 18 L/min, until the water temperature drops 17°C. Figure 6 shows the outlet temperature versus volume of water drawn.

Figure 6
Upper Zone Test

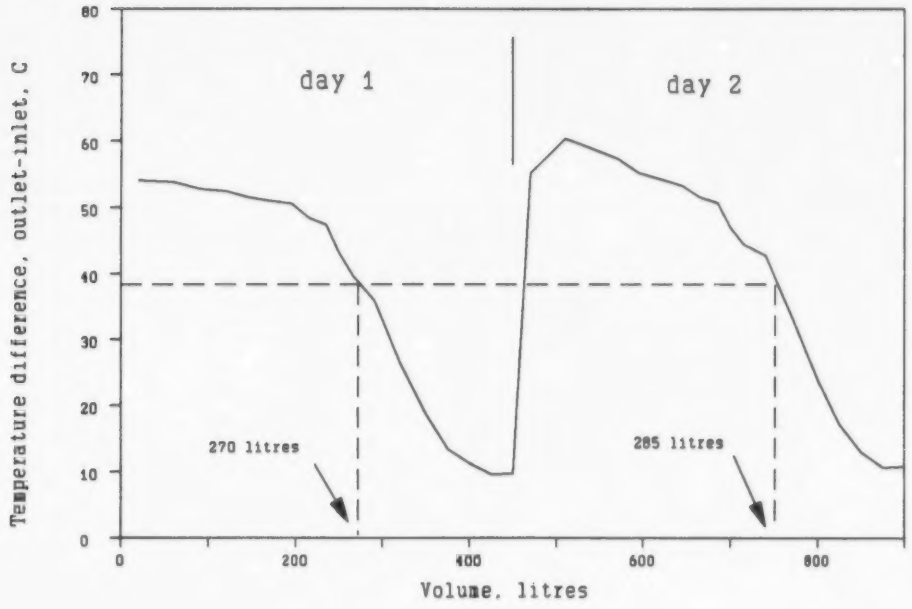


The tank flowed 126 litres before the water temperature dropped from 60.5 C to 43.5. The CSA requirement is a minimum of 25% of the total tank volume. This corresponds to 90.5 litres; consequently the tank met the test requirement.

Heating element input was measured, using a kilowatthour meter, for each element. The upper element has a measured power rating of 4406 W. The lower element is rated at 4363 W. Both these elements comply with the CSA requirement of 4500 W $\pm$ 5% (ie, $\pm$220 W)

The load management test consisted of switching the tank off for 16 hours beginning at 7:00 and ending at 23:00. A standard 175-litre storage water heater draw schedule was run during this period to determine the capability of the tank to provide hot water off-peak. The total water drawn during the off-peak period was 395 litres. Since this is larger than the tank volume, the outlet temperature was cold before the end of the off-peak period. Figure 7 shows the outlet water temperature as a function of total volume of water drawn. The tank supplied up to 285 litres of hot water before the outlet temperature dropped below the CSA requirement of 39°C above the inlet water temperature.

Figure 7
Load Management Test



Conclusions

1. The 350-litre electric storage water heater satisfied applicable clauses of the CSA Standard C191 Series-M1983.

2. The tank had a standby loss of 161 W. This relatively high for this size of tank.

3. Production units of this tank are expected to have a lower standby loss, by using high density fibreglass insulation and good construction practice.

4. The 350-litre tank may be suitable for load management applications where daily consumption is less than 285 litres.

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Reference

1. CSA C191 Series-M1983, CSA Standard on Performance of Electric Storage Tank Water Heaters - Performance of Electric Products. Canadian Standards Association, 1983.

Appendix A

CSA Draw Schedule

275 L tank

Draw Number (hours)	Volume (litres)
1	30
2	60
3	40
4	40
5	35
6	35
7	35
8	30
9	30
10	20
11	20
12	35
13	40
14	40
15	35
16	35
17	35
18	35
Total	630 litres